Adapting to Climate Change

January 2011

Executive Summary

1. Information on organisation	
Name of organisation	Dee Valley Water
Organisation's functions, mission, aims, and objectives affected by the impacts of climate change	Dee Valley Water is a water-only company supplying water to around 259,000 people in Chester, Wrexham and surrounding villages. Approximately 80% of the water we abstract is from the River Dee, 15% is from our own upland impounding reservoirs and the remaining 5% from groundwater resources. The main threat from climate change is perceived to be to maintaining an adequate and continuous supply of water to our customers.

2. Business preparedness before Direction to report was issued	
Has your organisation previously assessed the risks from climate change?	All water companies in England and Wales have a statutory duty to produce Water Resources Management Plans. The Guidance produced by the Environment Agency (EA) stipulates that the impact of climate change must be assessed in the supply/demand balance. We assessed the impact of climate change and included the uncertainty in the target headroom, which is the buffer a prudent water company allows between the supply and demand. We last assessed the target headroom in 2009.
If so, how were these risks and any mitigating action incorporated into the operation of your organisation?	The outcome of the target headroom assessment is that there is adequate available headroom up to the planning horizon of 2034/35. In view of this we will continue to monitor the available headroom on an annual basis to determine if mitigating actions are required.

3. Identifying risks due to the impacts of climate change	
What evidence, methods, expertise and level of investment have been used when investigating the potential impacts of climate change?	At this stage we have generally relied on in-house expertise to assess the impacts of climate change. We regularly attend climate change meetings to keep up-to-date on the latest developments and subscribe to research through UK Water Industry Research. We continue to liaise with the Environment Agency. As 80% of our water comes from the River Dee, which is operated by the EA, we are reliant on them carrying out climate change modelling on the River Dee for a better understanding of the impacts that climate change will have on the deployable output of this resource. We have obtained the UKCP09 forecasts for the Dee catchment and this information will be analysed and applied to determine the impact on the deployable output of the company-owned resources.

4. Assessing risks	
How does your organisation quantify the impact and likelihood of risks occurring?	Our approach to assessing the risk score depends on the assets that we are reviewing. In Section 4 of the main report we have set out an example of the scoring criteria we have used in our review of the risk from flooding at our pumping stations. As part of the flooding review we also assessed the cost impact to Dee Valley Water of losing a specific pumping station through flooding. From this information we were able to undertake a cost-benefit analysis and prioritise sites for mitigating action.

5. Uncertainties and assumptions	
What uncertainties have been identified in evaluating the risks due to climate change? What assumptions have been made?	In the short to medium term, the overall availability of water is forecast to remain broadly the same as current levels, albeit with increased seasonal variability. In view of the uncertainties regarding the impact this variability could have on the deployable output of water resources, it is important to adopt a flexible approach. One key uncertainty is to convince the Regulator that climate change is a key risk and requires a long-term view to adaptation.

6. Addressing current and future risks due to climate change - summary						
Climate variable (e.g. increase in temperature)	**Primary impact of climate variable (e.g. health)**	**Threshold(s) above which this will affect your organisation**	**Likelihood of threshold(s) being exceeded in the future and confidence in the assessment**	**Potential impacts on organisation and stakeholders**	**Proposed action to mitigate impact**	**Timescale over which risks are expected to materialise and action is planned**
Long periods (multi-season) of lower than average rainfall (decreased summer rainfall)	Lower river flows, particularly in the summer	Storage dropping below reservoir controls. Implementation of Drought General Directions	Short-term: Less than 1 in 40 years	Reduction in water supply - security of supply	Short-term: Increased demand-side activity Long-term: Invest in additional water resources	Short-term: 1 to 10 years Long-term: 20 to 50 years
Long periods (multi-season) of lower than average rainfall	Decrease in reservoir yields	Storage dropping below reservoir controls. Implementation of Drought General Directions	Short-term: Less than 1 in 40 years	Reduced water supply - security of supply	Short-term: Increased demand-side activity Long-term: Invest in additional water resources	Short-term: 1 to 10 years Long-term: 20 to 50 years

Climate variable (e.g. increase in temperature)	Primary impact of climate variable (e.g. health)	Threshold(s) above which this will affect your organisation	Likelihood of threshold(s) being exceeded in the future and confidence in the assessment	Potential impacts on organisation and stakeholders	Proposed action to mitigate impact	Timescale over which risks are expected to materialise and action is planned
Increased rainfall (either as increased long-term averages or more frequent and intense short duration rainfall)	Flooding of critical infrastructure and damage (water treatment works, reservoir embankments, river intakes)	Flooding event in excess of defence level	Short-term: 1 in 16 years	Pollution incidents; reduction in raw water quality and outage. Foul flooding from damage to water treatment works; disruption to supply of water.	Short-term: improve flooding resilience of at risk sites	Risks are expected to materialise in the short-term with mitigation action planned within the next five years
Increased rainfall	Increased soil erosion and sediment movement	TBC	Possible	Water quality problems	TBC	TBC
Changes in soil moisture	Lower summer groundwater tables	TBC	Possible	Water quality problems. Increase risk of pollution infiltration, affecting abstractions and groundwater-fed ecology	TBC	TBC

Climate variable (e.g. increase in temperature)	Primary impact of climate variable (e.g. health)	Threshold(s) above which this will affect your organisation	Likelihood of threshold(s) being exceeded in the future and confidence in the assessment	Potential impacts on organisation and stakeholders	Proposed action to mitigate impact	Timescale over which risks are expected to materialise and action is planned
Long periods (multi-season) of lower than average rainfall (decreased summer rainfall)	Lower river flows, particularly in the summer	TBC	Likely (Ref UKCP09 summer precipitation forecasts)	Raw water quality issues. Lack of dilution of effluent sewage and trade effluents eg Five Fords.	TBC	TBC
Long periods (multi-season) of lower than average rainfall (decreased summer rainfall)	Reduced groundwater recharge	TBC	Possible	Water supply - security of supply	TBC	TBC
Increased aridity (lower precipitation and higher temperatures)	Supply-demand deficit	Storage dropping below reservoir controls. Implementation of Drought General Directions	Short-term: Less than 1 in 40 years	Water supply - security of supply, increased competition for water. Increased opportunity for rainwater harvesting; increased frequency of restrictions on water reuse	Short-term: Increased demand-side activity Long-term: Invest in additional water resources	Short-term: 1 to 10 years Long-term: 20 to 50 years

Climate variable (e.g. increase in temperature)	Primary impact of climate variable (e.g. health)	Threshold(s) above which this will affect your organisation	Likelihood of threshold(s) being exceeded in the future and confidence in the assessment	Potential impacts on organisation and stakeholders	Proposed action to mitigate impact	Timescale over which risks are expected to materialise and action is planned
Intense rainfall	Sewer flooding	TBC	Possible	Raw water quality. Increased pollution incidents; contamination	TBC	TBC
Long periods (multi-season) of lower than average rainfall	Decrease in habitat provision	TBC	Possible	Reduced water availability for the environment	TBC	TBC
Periods of extreme low rainfall	Meteorological and hydrological drought affecting water supply/demand	Storage dropping below reservoir controls. Implementation of Drought General Directions	Short-term: Less than 1 in 40 years	Reduced water supply - security of supply. Rivers unable to meet WFD targets	Short-term: Increased demand-side activity Long-term: Invest in additional water resources	Short-term: 1 to 10 years Long-term: 20 to 50 years
Lower summer flows	Reduced water volumes into rivers thus less dilution of pollutants	TBC	Possible	Drinking water quality deterioration	TBC	TBC

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Higher soil moisture deficit	Pipe bursts/leakage	Failure to meet annual burst and leakage targets	May already be starting to see the impacts of climate change on the burst threshold	Increased frequency of pipe bursts - asset deterioration. Interruptions of supply to customers. Increase in numbers of customers affected by discoloured water	Medium-term: increase mains renewal rate above existing	It is possible the risks of increased bursts/leakage may materialise during AMP5. If this is the case then this should provide sufficient evidence that an increased rate of mains renewal is required in future AMPs
Wetter winters (increase in winter rainfall)	Increased opportunity for winter storage	Reduced pumping costs	Almost certain (Ref UKCIP09 winter precipitation charts)	Improved security of supply	Increased use of upland resources to reduce pumping costs	UKCP09 forecasts within the next 10 years

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Long period low rainfall levels / high temperatures	Deterioration in water quality	TBC	Possible	Raw water quality; Increased energy use from additional water treatment. Public health issues. Fish kills; reservoir water quality e.g. algal blooms	Maintain vigilant inspection of raw water resources. Utilise specific resources at certain times of year	Medium term: investigate ResMix solution to improve turnover of reservoirs
Intense rainfall events followed by sustained high temperatures	An increase in the incidences of cryptosporidium in water	TBC	Possible	Raw water quality	Increased monitoring.	TBC
Lower summer flows	Deposition of sediments	TBC	Unlikely	Raw water quality	TBC	TBC
Increased winter flows	Opportunity for greater hydropower production	TBC	Likely	Increased hydropower production	No mitigating action required – opportunity to increase revenue	TBC
Increase in winter rainfall; intense rainfall events	Reservoirs will be more prone to siltation from increased soil erosion	TBC	Possible	Reduced deployable output	Consider dredging of reservoirs	Medium to long-term

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More variable water into supply	Build up of contaminants in water distribution system	Failure of PCV standard	Likely	Drinking water quality deterioration	Consider additional air-scouring/flushing	Medium to long-term
Temperature rise	Higher demand from agriculture	Distribution input above x%	Possible	Increased abstraction/competition for water	Increase capacity of treatment works and service reservoirs. Implement additional demand side activities.	Medium- to long-term
Max summer temperature; increased evapotranspiration	Increased water demand	Distribution input above x%	Possible	Water supply - security of supply. Increased competition for water. Price increase.	Increase capacity of treatment works and service reservoirs. Implement additional demand-side activities.	Medium- to long-term

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Heatwaves	Decrease in (cool) water available for power station cooling and generation	TBC	Unlikely	Reduced water supply - power generation and risk of disruption to energy supply	TBC	TBC
Heatwaves; higher temperatures	Large increase in the demand for water	Distribution input above x%	Likely	Increased demand for water - peak household and industrial demands; power generation - increasing demand for water from the energy sector for cooling, particularly at peak demand times during the day	Increase supply and distribution capacity	Medium- to long-term
Temperature rise	Affect MEICA plant - increased rate of deterioration	Down-time in excess of x hours	Possible	Asset deterioration (water network)	Increase resilience of systems	Medium term: Accelerate asset replacement

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Higher temperatures - also humidity, wind speed and radiation	Increase in evaporation loss from open water sources (reservoirs)	TBC	Likely	Security of supply and micro-climate	Implement additional demand side activities	Medium term
Temperature rise	Algal growth	TBC	Possible	Drinking water quality deterioration	Monitor raw water quality and divert to alternative supplies	Medium term
Temperature rise	More efficient water treatment processes	x% of normal volume of chemicals used	Likely	Opportunity to lower opex costs	No mitigating action required	Medium term
Temperature rise	Discolouration	X number of discolouration complaints	Possible	Drinking water quality deterioration	Improve treatment processes	Medium term
Temperature rise	UV radiation - sunburn	TBC	Likely	Staff Health and Safety problems	Provide training and appropriate PPE including sunblock	Medium term
Increase in average summer temperature;	Contamination of water sources through	TBC	Possible	Raw water quality	Monitor raw water quality and divert to alternative	Medium term

heatwaves	recreational activity				supplies	
Climate variable (e.g. increase in temperature)	**Primary impact of climate variable (e.g. health)**	**Threshold(s) above which this will affect your organisation**	**Likelihood of threshold(s) being exceeded in the future and confidence in the assessment**	**Potential impacts on organisation and stakeholders**	**Proposed action to mitigate impact**	**Timescale over which risks are expected to materialise and action is planned**
Temperature rise	Greater microbial action causes chlorine depletion	TBC	Possible	Drinking water quality incidents	Increase Cl_2 dose	Medium term
Sea-level rise	Saline intrusion of the lower reaches of the River Dee	TBC	Unlikely	Security of supply	Move intake upstream	Medium term

7. Barriers to implementing adaptation programme	
What are the main barriers to implementing adaptive action?	We outline in Section 7 of the main report the three key barriers to implementation which are: cost and affordability, knowledge and resources and regulation/guidance. On cost and affordability we will need to educate our customers on the risks of climate change and the necessity to take action to ensure that they buy in to the investment. For knowledge and resources, we will need to develop our in-house expertise to translate the output from UKCP09 into outputs that we can use to assess the impacts on our operations. For regulation/guidance, we look to the regulators to provide clear and timely guidance and legislation on the priorities for investment. Without this it is unlikely that there will be significant adaptation.
Has the process of doing this assessment helped you identify barriers to adaptation that do not lie under your control?	One of the barriers to adaptation that does not lie under our control is the dependency on the power companies to implement climate change adaptation to ensure that the power supply to our above-ground assets is secure.

8. Report and review	
How will the outcome of the adaptation programme be monitored and evaluated and what is the timetable for this?	The adaptation programme will be monitored on an annual basis as part of the regulatory submissions (Table 10a and 10b) to Ofwat and the EA. In the short-term the adaptation programme is focused on improving flood resilience at our river intake pumping stations. These projects are due for completion in 2014/15. In addition, we are required to update our Water Resources Management Plans on a five-yearly cycle from the date of publication. We have not yet received direction from the Welsh Assembly Government to publish our WRMP and we are currently out of step with the rest of the water companies in England.
How do you propose to monitor the thresholds above which impacts will pose a threat to your organisation?	At this stage specific thresholds are being assessed to decide which are the most appropriate indicators of climate change as opposed to normal variability in the climate. However, we believe that we are gathering appropriate information across the business to enable us to assess whether a threshold is being exceeded. We detail in Section 4 of the main report our plans to

	improve the flooding resilience at our two river intake pumping stations by 2014/15. Once these works have been completed, the risk scores will be updated and another review carried out.
How will the benefits of the programme be realised and how will this feed into the next risk assessment and options appraisal?	The improvement in flooding resilience is generally considered to be a "no regrets" option as it will have many benefits for future generations.
Have you incorporated flexibility into your approach?	We have undertaken to carry out further detailed analysis of the climate change forecasts, which will enable us to select and implement the most cost effective mitigation options in a timely manner, i.e. implement the least whole-life cost options first. This will ensure that we maintain a flexible approach and elevate the "no regrets" options for earlier implementation.

9. Recognising opportunities	
What opportunities due to the effects of climate change and which the organisation can exploit have been identified?	The impacts of climate change do not generally lend themselves to opportunities as the changes will generally mean more investment and cost to customers. Overall, there might be some minor benefits but far outweighed by the changes needed. Three opportunities are perceived to be due to the effects of climate change but it is important to consider them in the context of the current regulatory regime: 1. Sell more water The benefits associated with this opportunity are limited due to Ofwat's Revenue Correction Mechanism, which reduces the revenue requirement in the following five years by the amount over-recovered, relative to the assumptions that Ofwat make when setting price limits so this is not really an opportunity. 2. Limited hydro-power generation We have identified a number of sites where it may be possible to generate a limited amount of hydro-electric power but in the current regulatory regime it is not currently financed. 3. More efficient treatment processes The benefits from milder weather may improve the efficiency of treatment processes by requiring fewer chemicals, but the benefit is expected to be marginal and even so the increased sediment may offset the benefit

CONTENTS **Page**

1. INTRODUCTION

1.1 The Climate Change Act

The Climate Change Act 2008 gives Government the power to direct certain public bodies to report on their climate risks and adaptation plans. All water and sewerage companies in England have been directed by the Secretary of State to report under this power. The Welsh Assembly Government has not asked us to report because they are adopting a reactive approach to use of the reporting power. However, we were asked to prepare and submit a report alongside the other water and sewerage companies in England and Wales following the guidance and timescales set out by Defra.

We believe that preparing and submitting this report will demonstrate that we are committed to understanding the risks to Dee Valley Water associated with climate change and will enable us to take appropriate action to minimise those risks.

1.2 Function of Dee Valley Water

Dee Valley Water supplies water only and does not deal with sewerage, although we do collect sewerage charges on behalf of the sewerage companies in our area. The area supplied covers 831 square kilometres in north-east Wales centred around Wrexham and in north-west England centred around Chester. Dee Valley Water provides water to a population of over 250,000 and many local industries rely on us for a safe, reliable supply of water. Our services are vital to the ongoing health and welfare of the community we serve as well as the economic wellbeing of the area.

About 80% of our raw water is derived from the River Dee; 15% is from our own reservoirs situated in the nearby Welsh hills and the remaining 5% is from two underground sources.

Although only a small company in terms of turnover, we employ a very large asset base consisting of approximately 2,000 kilometres of water mains, 6 treatment works and over 30 water storage tanks and over 30 pumping stations – in total, their replacement cost is over £300 million.

We recognise that, as the environment and our customers' expectations change, we will also need to evolve to meet these changes. Our vision of the future will therefore change and this Adaptation Report will need to be updated from time to time.

We set out our key objectives in our Strategic Direction Statement (SDS), which we published in December 2007. The SDS comprised our view of how we see the future and how this will influence our key objectives, which include maintaining a consistent supply of wholesome water that gives customers good value for money.

1.3 Functions affected by climate change

Dee Valley Water provides a vital service to the local community, supplying good quality wholesome water. The most significant impacts of climate change on the function of Dee Valley Water are likely to be:

- increase in demand
- decrease in supply
- deterioration of water quality
- increase in flooding leading to problems with treatment.

The greatest threat from climate change is to security of supply. Drier summers and more variable rainfall patterns in other seasons increase the likelihood of drought and disruptions to supply. Rising sea levels and saline intrusion to the lower reaches of the River Dee will also reduce the available resource. Conversely, there is a minor opportunity in the form of increased winter rainfall bringing the potential for an increase in storage.

Water quality may be affected as warmer temperatures increase the risk of algal blooms, and the increased risk of flooding of river intakes or water treatment works may increase the risk of temporary shutdown.

In addition to direct physical impacts, climate change will have indirect impacts. An increase in population due to an influx of climate migrants may increase the demand for water.
At this stage, it has been difficult to identify specific climate thresholds above which climate change and weather events will pose a threat to Dee Valley Water. Some indicators that could be used as a surrogate for climate thresholds may be:

- peak daily treatment works output exceeding (100-x)% of total treatment works capacity
- 7-day average output from treatment works exceeding (100-x)% of total treatment works capacity
- closing to within x% of target headroom
- per capita consumption figures increasing by x%.

We will continue to work with the industry to assess whether more appropriate indicators can be derived from data that we already collect.

2. APPROACH

2.1 Evaluation of future climate impacts

During 2010, we undertook a qualitative assessment of our infrastructure and operational climate change risks. The assessment involved senior managers from all departments expected to be impacted upon by climate change with additional assessments undertaken by the Planning and Regulation Department and the Water Quality Department.

The starting point for this initial risk assessment was based on information obtained from the Climate Change Risk Assessment – Water Workshop that was held in Reading on 24 May 2010.

The risk assessment identified a large number of potential climate change risks for Dee Valley Water. These risks have been classified under seven categories and are generally assigned to departmental managers to monitor and manage:

1. Resource demand risks.
2. Economic risks.
3. Risks to assets.
4. Risks to safety.
5. Regulatory risks.
6. Business service (operational) risks, and
7. Planning risks.

The outcomes of the first stage identified that while climate change will present economic and social challenges and opportunities, the Company is well positioned to respond. This is due to:

- an understanding of how climate and weather influence current operations
- an adaptive management approach embedded in planning and risk management.

Specifically, the assessment identified that climate change risks to Dee Valley Water infrastructure include:

- more frequent or intense extreme events (flooding of river intakes, severe winter weather causing more mains bursts)
- higher temperatures and lower flows in the River Dee that impact upon the raw water quality
- drier soils damaging infrastructure assets and leading to more mains bursts
- conditions that are more favourable for blue green algal blooms in raw water supplies.

Other risks are related to impacts on the Supply/Demand Balance. These include:

- higher temperatures, lower (and potentially less regular) rainfall and higher evaporation
- higher temperatures and longer dry periods leading to increased customer demand, particularly for outdoor water use.

As a result of undertaking this risk assessment, Dee Valley Water has recognized that many risks identified in the process are already addressed. However, climate change has the potential to alter the likelihood and the consequence of those risks occurring.

2.2 Climate change projections

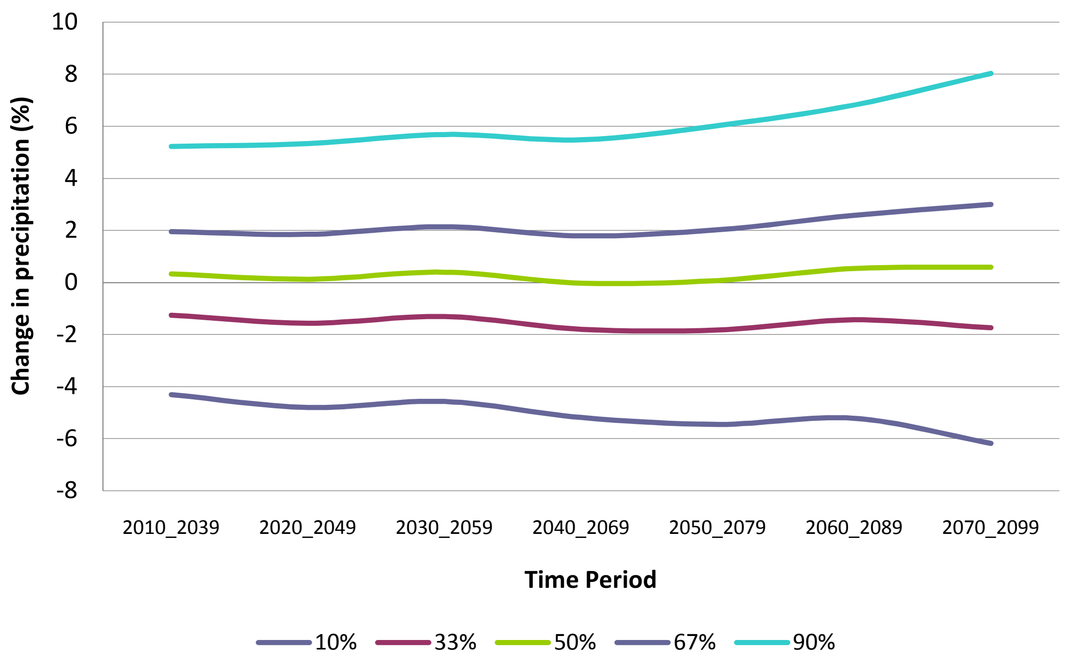
In June 2009, the UK Climate Impacts Programme published projections of how the UK climate is projected to change during the 21st century. The projections allow an analysis of different climate variables, such as temperature or rainfall, for river basins such as the River Dee. Data downloaded from the UK Climate Impacts Project 09 (http://ukclimateprojections.defra.gov.uk/) is illustrated in the following figures for selected key climate variables for the River Dee river basin.

The figures are based on a high emissions scenario to represent the worst case scenario. It is estimated that there is a 30-year time lag between the time carbon dioxide is emitted and how the climate responds, and the climate projections for low, medium or high emissions will therefore not differ by much up to 2040. The figures below show the change in climate averages relative to the period 1961 to 1990.

The key points to note (for the central estimate) are:

1. Annual rainfall will remain about the same up to the 2080s.
2. Drier summers, with 24% less rainfall by the 2080s.
3. Wetter winters, with 16% more rainfall by the 2080s.
4. Warmer summers, with an average increase in the warmest day of $4^{o}C$ by the 2080s.

Figure 1 - River Dee Basin - Projected change in annual precipitation
Emissions scenario: High



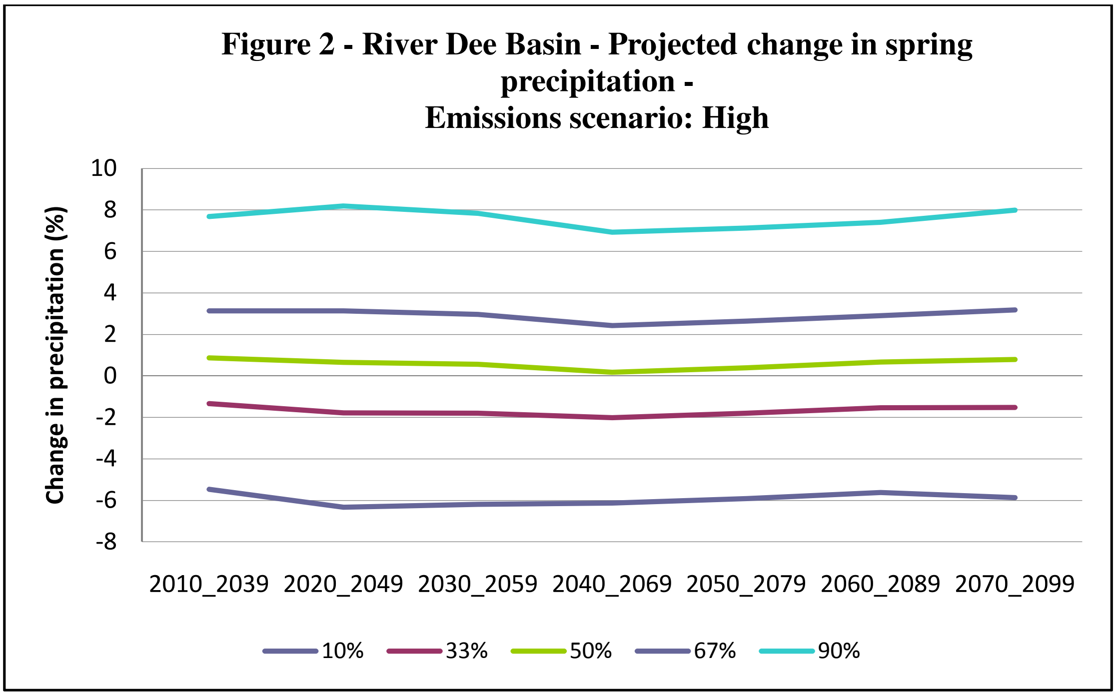


Figure 2 - River Dee Basin - Projected change in spring precipitation - Emissions scenario: High
Change in precipitation (%)
10
8
6
4
2
0
-2
-4
-6
-8
2010_2039 2020_2049 2030_2059 2040_2069 2050_2079 2060_2089 2070_2099
10%
33%
50%
67%
90%

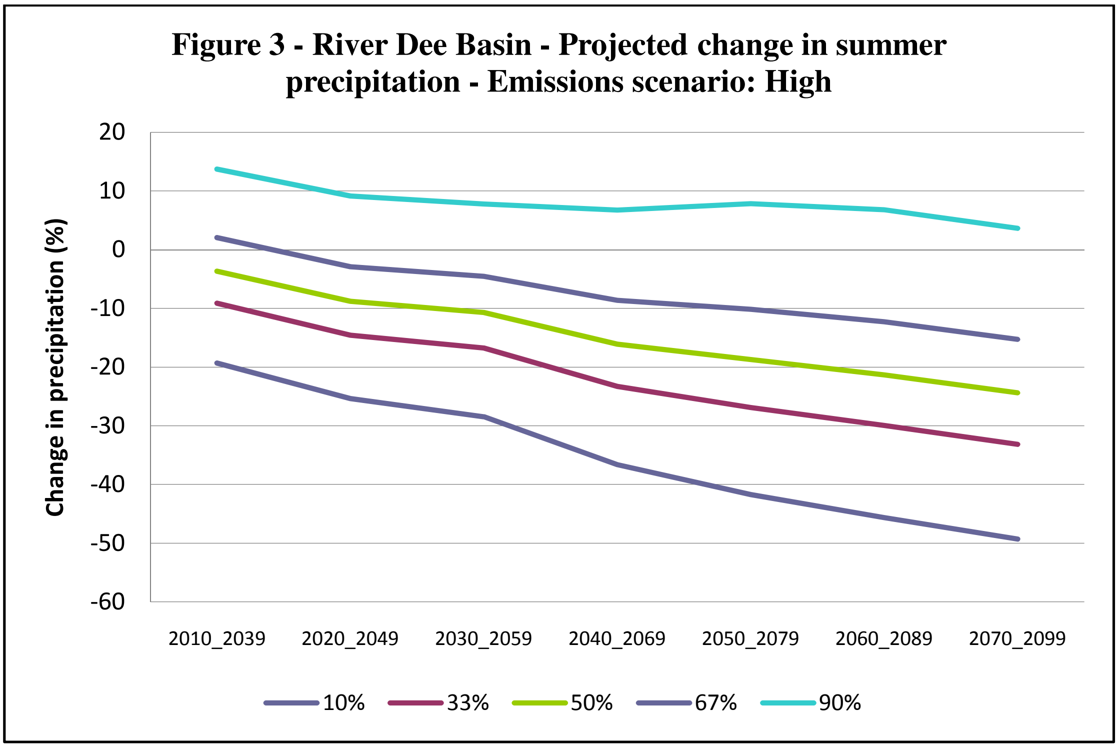


Figure 3 - River Dee Basin - Projected change in summer precipitation - Emissions scenario: High
Change in precipitation (%)
20
10
0
-10
-20
-30
-40
-50
-60
2010_2039 2020_2049 2030_2059 2040_2069 2050_2079 2060_2089 2070_2099
10%
33%
50%
67%
90%

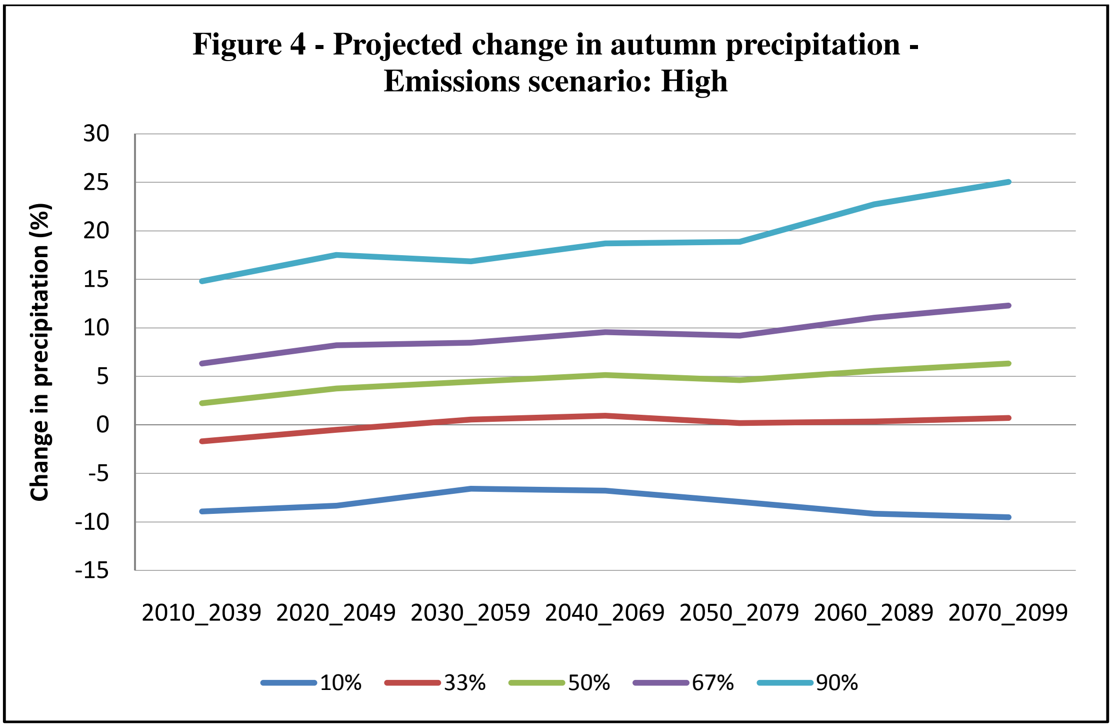


Figure 4 - Projected change in autumn precipitation - Emissions scenario: High
Change in precipitation (%)
30
25
20
15
10
5
0
-5
-10
-15
2010_2039
2020_2049
2030_2059
2040_2069
2050_2079
2060_2089
2070_2099
10%
33%
50%
67%
90%

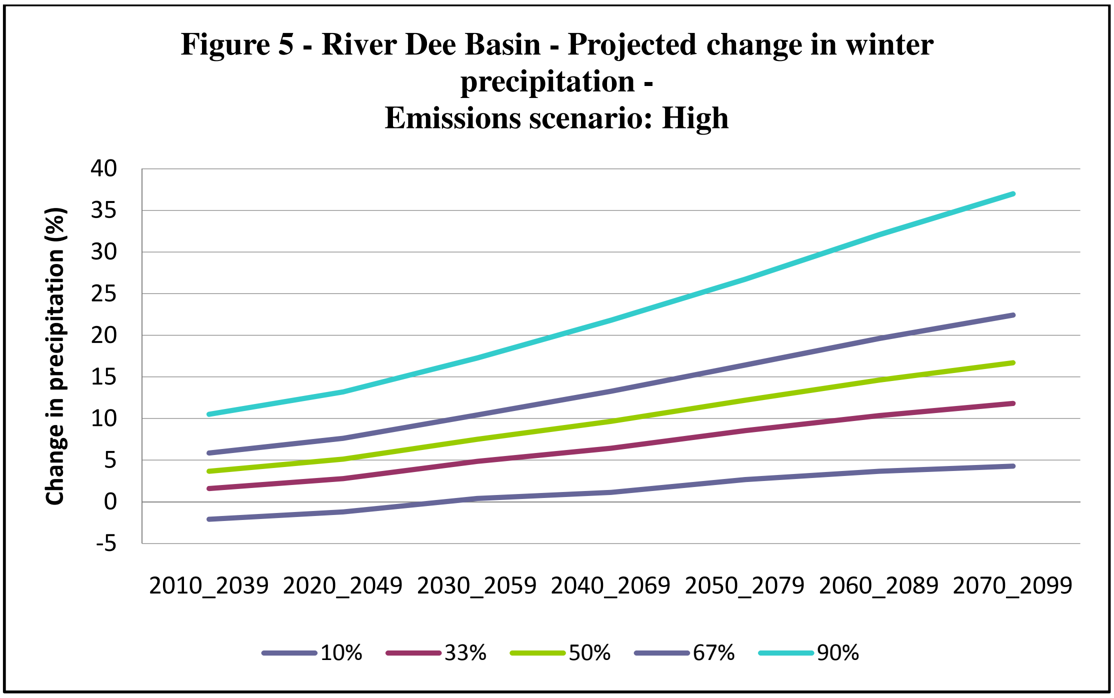
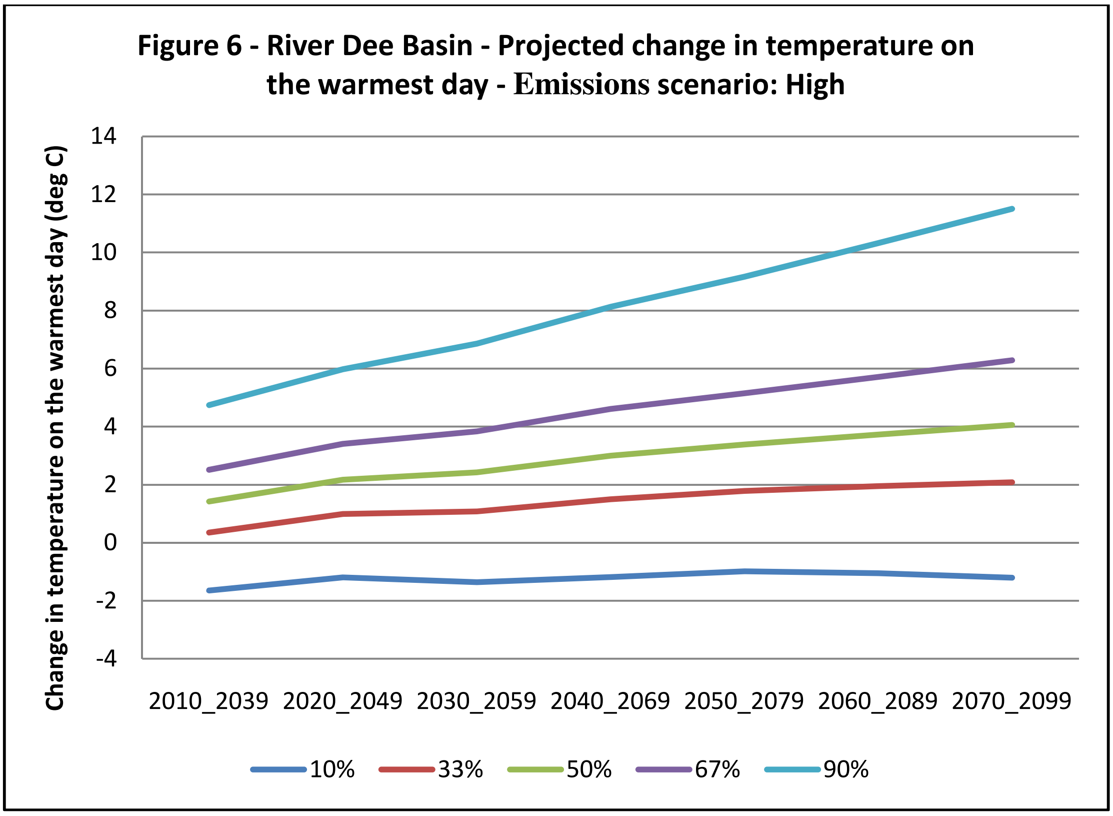


Figure 5 - River Dee Basin - Projected change in winter precipitation - Emissions scenario: High
Change in precipitation (%)
40
35
30
25
20
15
10
5
0
-5
2010_2039
2020_2049
2030_2059
2040_2069
2050_2079
2060_2089
2070_2099
10%
33%
50%
67%
90%



3. SUMMARY OF RISKS

Many of the risks identified in the climate change risk assessment carried out during 2010 align with many of the risks already identified in the Company's Water Safety Plan. Many of the climate change risks are already being managed as part of a business-as-usual process.

The key risks identified during the climate change risk assessment phase are shown in Table 1.

Table 1 – Climate change risk assessment

	Climate effects	Impacts	Threat/ Opportunity/ Neutral	Consequences	Risk	Level of confidence
Main climate driver: Changes in annual, seasonal or daily precipitation						
1	Long periods (multi-season) of lower than average rainfall (decreased summer rainfall)	Lower river flows, particularly in the summer		Reduction in water supply - security of supply	3	M
2	Long periods (multi-season) of lower than average rainfall	Decrease in reservoir yields		Reduced water supply - security of supply	3	M
3	Increased rainfall (either as increased long-term averages or more frequent and intense short duration rainfall)	Flooding of critical infrastructure and damage (water treatment works, dams, river intakes)		Pollution incidents; reduction in raw water quality and outage. Foul flooding from damage to water treatment works; disruption to supply of water. Dams – uncontrolled large releases of water resulting in flooding	3	H
4	Increased rainfall	Increased soil erosion and sediment movement		Water quality problems	2	H
5	Changes in soil moisture	Lower summer groundwater tables		Water quality problems. Increase risk of pollution infiltration, affecting abstractions and groundwater-fed ecology	2	M
6	Long periods (multi-season) of lower than average rainfall (decreased summer rainfall)	Lower river flows, particularly in the summer		Raw water quality issues. Lack of dilution of effluent sewage and trade effluents eg Five Fords.	2	M

	Climate effects	Impacts	Threat/ Opportunity/ Neutral	Consequences	Risk	Level of confidence
7	Long periods (multi-season) of lower than average rainfall (decreased summer rainfall)	Reduced groundwater recharge		Water supply - security of supply	2	M
8	Increased aridity (lower precipitation and higher temperatures)	Supply-demand deficit		Water supply - security of supply, increased competition for water. Increased opportunity for rainwater harvesting; increased frequency of restrictions on water reuse	2	M
9	Intense rainfall	Sewer flooding		Raw water quality. Increased pollution incidents; contamination	2	M
10	Long periods (multi-season) of lower than average rainfall	Decrease in habitat provision		Reduced water availability for the environment	2	M
11	Periods of extreme low rainfall	Meteorological and hydrological drought affecting water supply/demand		Reduced water supply - security of supply. Rivers unable to meet WFD targets	2	M
12	Lower summer flows	Reduced water volumes into rivers thus less dilution of pollutants		Drinking water quality deterioration	2	M
13	Higher soil moisture deficit	Pipe bursts/leakage		Increased frequency of pipe bursts - asset deterioration	1	H
14	Wetter winters (increase in winter rainfall)	Increased opportunity for winter storage		Improved security of supply	1	H

	Climate effects	Impacts	Threat/ Opportunity/ Neutral	Consequences	Risk	Level of confidence
15	Long period low rainfall levels / high temperatures	Deterioration in water quality		Raw water quality; Increased energy use from additional water treatment. Public health issues. Fish kills; reservoir water quality e.g. algal blooms	1	M
16	Intense rainfall events followed by sustained high temperatures	An increase in the incidences of cryptosporidium in water		Raw water quality	1	M
17	Lower summer flows	Deposition of sediments		Raw water quality	1	M
18	Increased winter flows	Opportunity for greater hydropower production		Increased hydropower production	1	M
19	Increase in winter rainfall; intense rainfall events	Impounding reservoirs will be more prone to siltation from increased soil erosion		Reduced deployable output	1	L
20	More variable water into supply	Build up of contaminants in water distribution system		Drinking water quality deterioration	1	M
Main climate driver: Changes in annual, seasonal or extreme temperature						
21	Temperature rise	Higher demand from agriculture		Increased abstraction/competition for water	3	M
22	Max summer temperature; increased evapotranspiration	Increased water demand		Water supply - security of supply. Increased competition for water. Price increase.	2	H

	Climate effects	Impacts	Threat/ Opportunity/ Neutral	Consequences	Risk	Level of confidence
23	Heatwaves	Decrease in (cool) water available for power station cooling and generation		Reduced water supply - power generation and risk of disruption to energy supply	2	M
24	Heatwaves; higher temperatures	Large increase in the demand for water		Increased demand for water - peak household and industrial demands; power generation - increasing demand for water from the energy sector for cooling, particularly at peak demand times during the day	2	M
25	Temperature rise	Affect MEICA plant - increased rate of deterioration		Asset deterioration (water network)	2	M
26	Higher temperatures - also humidity, wind speed and radiation	Increase in evaporation loss from open water sources (reservoirs)		Security of supply and micro-climate	1	M
27	Temperature rise	Algal growth		Drinking water quality deterioration	1	M
28	Temperature rise	More efficient water treatment processes		Opportunity to lower opex costs	1	M
29	Temperature rise	Discolouration		Drinking water quality deterioration	1	M
30	Temperature rise	UV radiation - sunburn		Staff Health and Safety problems	1	M
31	Increase in average summer temperature; heatwaves	Contamination of water sources through recreational activity		Raw water quality	0	M
32	Temperature rise	Greater microbial action causes chlorine depletion		Drinking water quality incidents	0	M

Main climate driver: Changes in sea level						
	Climate effects	**Impacts**	**Threat/ Opportunity/ Neutral**	**Consequences**	**Risk**	**Level of confidence**
33	Sea-level rise	Saline intrusion of the lower reaches of the River Dee		Security of supply	1	H

4. ACTIONS PROPOSED TO ADDRESS RISKS

The highest risk with the highest confidence level relates to increased rainfall and the potential to cause flooding of critical infrastructure. Our analysis of this risk is included in the following section under flooding resilience.

4.1 Flooding resilience

In the light of the increased focus on flooding resilience following events in 2007, Dee Valley Water reviewed the risk of flooding of all of its assets as part of its Capital Maintenance Common Framework risk assessment work for the Periodic Review 2009. The assessment of the Company's asset resilience to flooding and the proposed risk management interventions is based on Halcrow's *Asset Resilience to Flood Hazards: Development of an analytical framework*.

4.2 Risk screening

The classification of risk described below was carried out before Halcrow's *Asset Resilience to Flood Hazards: Development of an analytical framework* was published. The classification of risk was by a systematic high-level assessment of flooding risk (both fluvial and pluvial) based on observations made during the asset condition re-survey of the Company's assets carried out by Tynemarch for Periodic Review 2009. This involved site visits to all operational treatment and pumping station sites. Assets were graded as follows:

1. No conceivable mechanism by which site could be flooded.
2. Flooding could conceivably occur.
3. Obvious risk of flooding.

Due to the nature of service reservoirs, which are generally at high elevations, the risk of flooding has been considered low, and is therefore not included in this analysis. Only four of the Company's assets were graded 2 or 3. Two of the assets were, as expected, the structures on the River Dee: the Sesswick intake, and the Barrelwell Hill intake and pumping station (one site but two assets). These are strategically important assets for which the consequences of loss would be serious. The other two sites were the Plas Newydd and Penycae booster stations. Risk Screening using the Environment Agency's (EA) flood maps was tried but the information is insufficiently detailed to be able to make a sound assessment of risk. Potential vulnerability of pipe crossings of rivers has been investigated. More study of this group of assets will be carried out between 2010 and 2015.

A desktop study was then carried out to assess the consequence of failure of the asset. This also took into account mitigation measures that were already in place. Assets were assessed as follows:

1. Low consequence – small to medium capacity booster stations or similar.
2. Medium consequence – medium to large booster stations and small treatment works with mitigation available.

3 High consequence – large treatment or abstraction pumping stations with no or limited mitigation available.

The results of the two assessments were then multiplied together to provide a risk position for each site - this is presented in Figure 7. The Company then assessed each risk score based on the criteria in Table 2.

Table 2 - Risk score criterion

Score	**Description**
<3	No perceived risk of flooding at this time - review in 10 years
>3 and <6	Slight risk of flooding with low consequence or low risk of flooding with medium consequence - review every 5 years
>6	Risk of flooding with high consequence carry out further investigation / consider resilience measures

The Company has three assets which required further investigation:

1. Sesswick pumping station.
2. Barrelwell Hill pumping station.
3. Barrelwell Hill intake.

Barrelwell Hill pumping station and the Barrelwell Hill intake are on opposite banks of the same stretch of the River Dee in Chester and are treated as one site for the investigation as they are effectively at the same risk of flooding. Barrelwell Hill pumping station supplies raw water to Boughton treatment works, which then feeds the City of Chester. Barrelwell Hill is the only raw water source supplying Boughton. Boughton is the Company's second largest treatment works after Llwyn Onn and is the only treatment works able to supply Chester.

Sesswick pumping station supplies raw water to Llwyn Onn treatment works. Llwyn Onn can only be supplied with sufficient quantities of raw water from Sesswick; there is no alternative. Llwyn Onn is the Company's largest treatment works and supplies water to Wrexham and the surrounding area. No alternative supply is available for much of the area supplied in the event of a loss of Llwyn Onn or Sesswick pumping station.

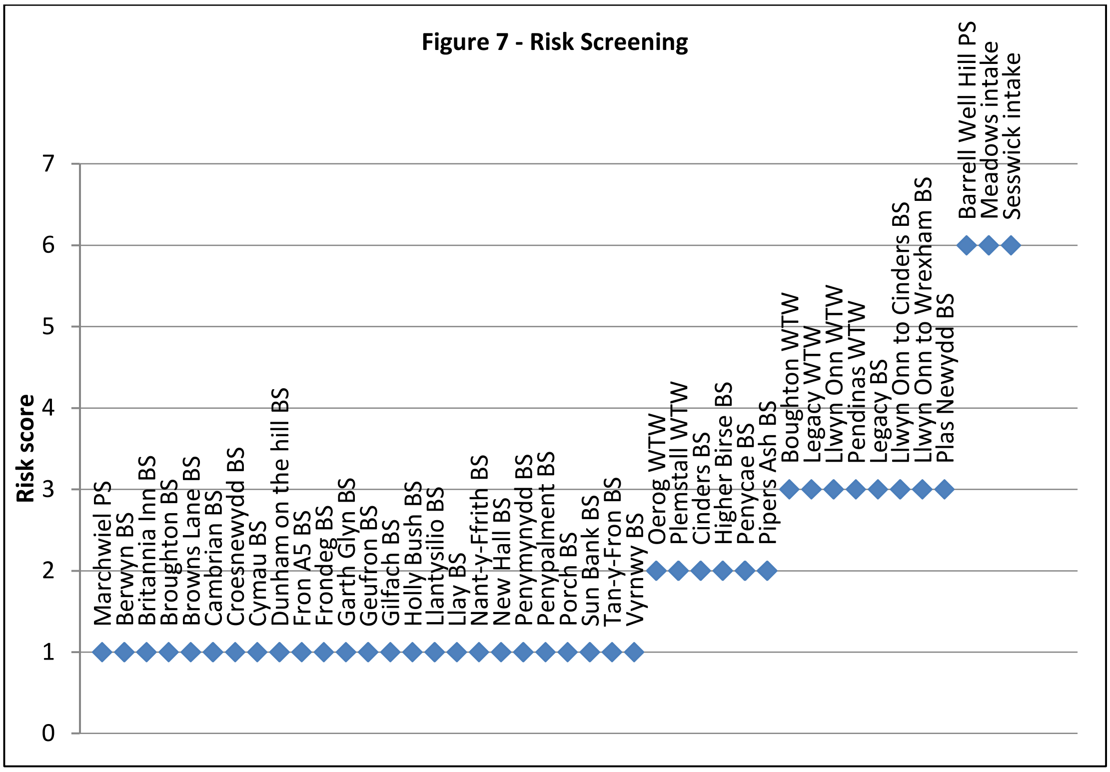


Figure 7 - Risk Screening

Sesswick pumping station was also identified during modelling work for Availability, Reliability and Maintainability (ARM) analysis undertaken by risk consultants Holista. This analysis identified assets which carry a potentially significant risk to the Company's operations.

Some flood level return periods have been obtained from the EA for the two River Dee sites. The EA has made no allowance for the future effects of climate change within their figures. It has been suggested that companies should have sufficient resilience within their infrastructures to be able to survive the loss of a major works without any interruption to supply. This would require considerable investment and is not allowed for at this stage.

The Water Safety Plan provided additional evidence that support the flood defence works at Sesswick pumping station.

4.3 Risk analysis

The Company instructed consulting engineers Black and Veatch (BV) to carry out detailed studies of both Sesswick pumping station and Barrelwell Hill pumping station / intake. The Company has also reviewed available data and consulted with members of staff with long experience of high water levels at both sites. Both investigations are summarised below.

Sesswick intake pumping station

The particular problem at this station is that the pumpsets and some starters are significantly below the current defence level. This means that the equipment is inundated as soon as a flood exceeds the defence level. This is illustrated by Figure 8, which shows the height of the entrance threshold (the last line of defence and just above the design defence level) in relation to the pumping equipment.

Figure 8 – showing the vulnerability of the station to flooding and the existing flood inundation point (16.05mAOD)

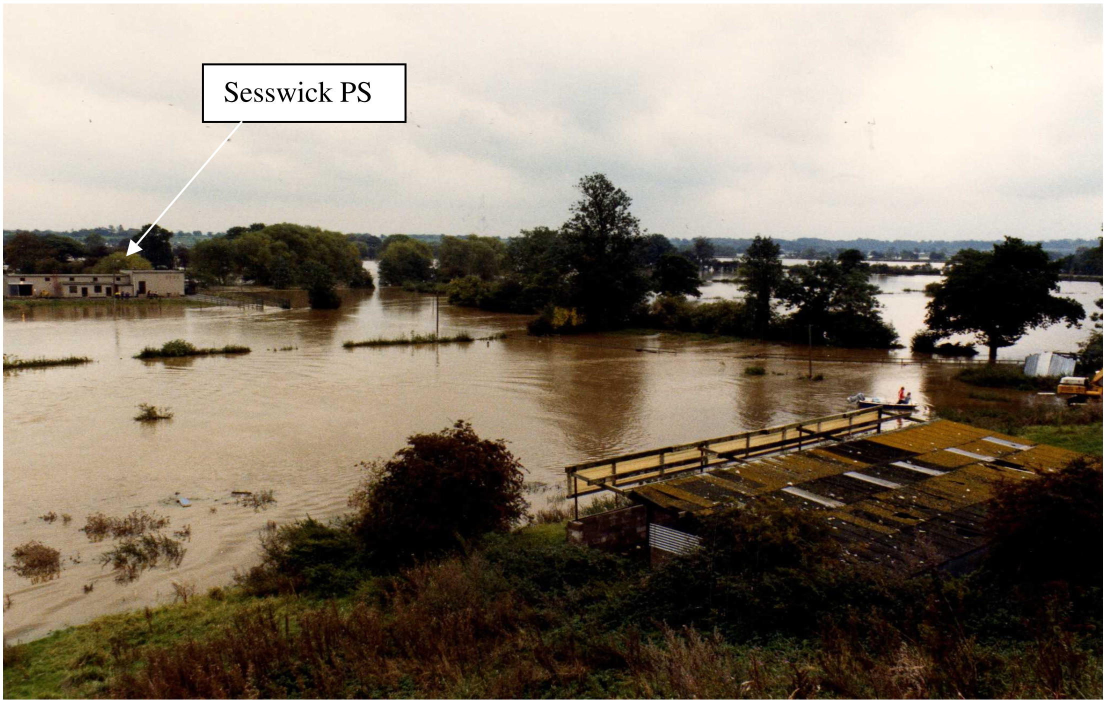
The EA has provided a flood level at this site of 15.81mAOD with a 100 year return period. This has been extracted from a hydrodynamic ISIS model of the River Dee. EA can give no accuracy to this level due to the 'large unknowns'; however recent discussions have revealed that $\pm$500mm accuracy is normal but $\pm$300mm is more likely.

BV modelled a 1,000 year return period flood level using the same information used to model the 100 year return period. A 1,000 year return period flood level of 16.11mAOD has been calculated. The pumping station is understood to have been originally designed to a flood level of 15.54mAOD, however no details on a design return period is available. The level of the threshold of the pumping station is 16.05m. The river level in 2001 is estimated to have reached to within 150mm (6-7 inches) of the threshold, which is higher than EA's 100 year return period level and significantly higher than the original design level. A previous flood in 1964 is estimated to have reached to within about 300mm of the threshold, again exceeding the EA's 100 year level and significantly higher than the design level for the site, and this was before the attenuating effect of the Dee impounding reservoirs was in place.

Whilst there has to be some uncertainty about the precise flood levels reached in the past, as they have been estimated from memory, the floodwater has come close to inundating the pumping station. This can be seen in Figures 9 and 10 showing floodwater encircling the whole site on two occasions. Floodwater has encircled the site on several other occasions, most recently in January 2008. This, combined with the high consequences of failure of this station, makes it a high risk.

Figure 9 – Sesswick Pumping Station 1964/65

Figure 10 - Sesswick pumping station 2000/01



The Company has obtained flow data for the River Dee for two gauging stations 11km upstream of the pumping station. This has enabled the calculation of return periods for the 1964/65 and 2000/01 floods. This showed that the 1964/65 flood had a return period of 80 years with a flow of 617m^3/s and the 2000/01 flood had a return period of just 16 years with a flow of 444m^3/s. Therefore, even with a significantly reduced flow a similar or even higher flood level is now being seen at the pumping station. This is almost certainly due to changes in the catchment such as the flood defence and a road bypass scheme for the nearby village of Bangor-on-Dee. The contribution of climate change is not known. It is therefore concluded that flood protection level at the pumping station has reduced from an 80 year return period to a 16 year return period since 1964/65. A re-establishment of the original level of protection of an 80 year return period is proposed.

Barrelwell Hill pumping station and Meadows intake

EA has provided a flood level of 6.96mAOD at this site for a 100 year return period and 7.35mAOD for a 1,000 year return period flood. These flood levels are understood to be dictated by tide rather than runoff, and based on record drawings, the pumping station has been designed to a Highest Recorded Water Level (HRWL) of 6.81m (22.35 ft) – slightly lower than the 100 year flood. There are no reports of operational problems having occurred due to flooding at either the intake on the south side of the river or the pumping station to the north side, and the levels provided are consistent with operational experience at the site.

The intake has been designed so that, should flood water enter the building, the machinery is located some way above the floor level. This allows the intake to keep operating even if inundated with floodwater at a greater level than a 100 year return period. Even if an allowance for freeboard is made, the intake should continue to operate, albeit not so effectively. Therefore, no flood protection work is required at the intake at this time. At the pumping station, a threshold of only 6.815mAOD is available if water is to be excluded from the site. However, for water to affect pumping the electrical equipment on the floor of the pumping station at a level of 7.145mAOD needs to be reached – this therefore forms the existing threshold. This is marginally above the EA's 100 year flood level, excluding freeboard. However, with an allowance for freeboard a 100 year return period requires a defence level of 7.51 mAOD, which is significantly higher than currently available. The pumping station boundary wall has been breached on a number of locations, to provide access to a landing stage on the river, which is no longer in use, and for construction of a now-disused access gate. The Company has received additional flood level data from the EA in the form of maximum water level reached at the Chester Weir, 1km downstream of the pumping station. This data has been used to calculate two flood level return periods, firstly the level at which electrical equipment is affected within the pumping station and secondly if the existing defences are restored to original levels. Freeboard estimates have been excluded from the calculation. The calculated return period for the existing level of protection is approximately 21 years. After taking into account the proposed repairs to the existing boundary walls, the protection afforded increases to the level of a 70 year return period event, which is equivalent to the original design defence level.

4.4 Risk management

Sesswick intake pumping station

Flood protection level at the pumping station has reduced from an 80 year return period to a 16 year return period since 1964/65. A return to the original level of protection of an 80 year return period is required. The nearby (1km away) village of Bangor-on-Dee has varying degrees of protection up to a level of 16.83mAOD. As pointed out in the BV report, there is some merit in protecting the water supply to customers to the same level as afforded to their properties. BV recommended protecting the pumping station to this level at a cost of £330k with the construction of a concrete wall and small infill works to the existing building. The Company carried out sensitivity analysis by estimating the cost, assuming a nominal 250mm lower flood defence level. This analysis showed a cost saving of just £2k, indicating that the cost is insensitive to small changes to the final design level.

Figure 11 – Sesswick pumping station showing pedestrian access bridge prior to its removal in the early 1970's

At Sesswick, there is also the problem of lack of access during a flood, as can be seen in Figure 10. This prevents checking of equipment and even rudimentary improvement of flood protection, by sandbagging for example. Prior to the early 1970's there was a walkway to the pumping station but it was abandoned due, it is understood, to maintenance costs and the understanding that it would not be needed again with the construction of the Dee impounding reservoirs. The structure can be seen in Figure 10 and in Figure 8 under flood conditions. Access to the site needs to be replaced to allow for essential maintenance during times of flood. It is proposed that replacement of a safe method of accessing the pumping station during a flood be established. The pumping station should be able to operate normally with a flood up to the proposed protection level. This will require improved sealing of any holes into the structure and also protection of the bandscreen, the transformer and any other vulnerable equipment at the station. This has been included in the protection cost.

A site assessment has established that there are currently two separate incoming electrical supplies to the site, each having it own transformer. Therefore adequate backup is already in place in the event of a local electrical outage. The facility to connect temporary generation in the event of major grid failure is available, given adequate access during flood conditions. It is proposed that the pumping station be protected against flooding to a nominal level of 780mm above the existing threshold level. This protection level would cover any uncertainty about the predicted flood level, including the effects of climate change, and allow a reasonable wave freeboard (600mm is the minimum that would be applied for a Category B dam). Also, it would protect to the same level as the nearby village of Bangor-on-Dee. Given the insensitivity of the cost to relatively small variations in the absolute defence level, the proposed level is reasonable. This would return the site to a similar level of protection to that to which it was originally designed.

The Company has used the return periods calculated and estimates provided by BV to carry out cost benefit analysis. This showed a significant benefit in carrying out the scheme during the AMP5 period.

In summary, the proposals for Sesswick PS are:

- Provide defence for water reaching to 78mm above the existing threshold level to ensure continuation of normal operation and to return protection to the original design event frequency in the region of 1 in 80 years return period. This involves construction of a concrete wall and small scale infill works to the building.
- Provide safe access to the pumping station consistent with the proposed flood defence level. Man access will be adequate but any capacity requirements for carrying over materials (e.g. portable generator cable etc.) need to be considered.
- When pump upsizing is being assessed, further cost-effective measures inside the station to protect against some water ingress will be considered.

Barrelwell Hill pumping station and Meadows intake

The pumping station boundary wall has been breached in a number of locations, to provide access to a landing stage on the river which is no longer in use and for construction of a now disused access gate.

The calculated return period for the existing defence level is approximately 21 years. After taking into account the repairs to the existing boundary walls, the protection afforded increases to a 70 year return period. Repairing the boundary wall will increase the defence level by approximately 280mm above the existing threshold level, to 7.42mAOD. Further other small-scale works by infilling holes in the building will further increase this level. This small-scale work is prudent and cost-effective given the uncertainty about the effects of climate change and the lack of freeboard currently available.

The Company has used the return periods calculated and estimates provided by BV to carry out cost benefit analysis. This showed a significant benefit in carrying out the scheme during the AMP5 period. The full results of this analysis are shown in Table 3.

Table 3 - Cost benefit analysis results

Name of Scheme	Net Present Value (£)	Benefit Cost Ratio*
Sesswick Flood Defence	6,333,635	8.209
Barrelwell Hill Flood Defence	1,158,303	35.474

*>1 - indicates scheme is cost beneficial.

In summary, the proposals for Barrelwell Hill PS are to carry out small-scale works to restore the flood protection to its original level by repairing the boundary wall. Other work such as infilling holes to the building should bring the level of protection close to historical level and close to the 100 year return period proposed in the BV report.

Both of these projects were approved by Ofwat in their Final Determination in 2009 and they will be completed during AMP5 (2010-2015).

5. UNCERTAINTIES AND ASSUMPTIONS

Of the 33 key risks identified in Table 1, just three were ranked as a high risk and hence a priority for further investigation/action. The first two high risks have a medium confidence score and consequently it will be necessary to carry out further research to inform Dee Valley Water's adaptation response. In order to continue to develop our understanding of the implications of climate change for these two key risks and ensure that we have a robust evidence base we will:

- improve our understanding of the impact of climate change on the availability of, and demand for, water
- work with others to assess how climate change will impact on the frequency and intensity of drought and security of water supplies
- use UKCP09 to assess the impact on our own water resources
- monitor the effects of climate change.

We noted in the introduction that we rely on the River Dee for about 80% of the water that we abstract. The Environment Agency (EA) is responsible for monitoring and operating the River Dee. We are liaising with the EA to understand the impact climate change will have and they are in the process of modelling differing scenarios on the River Dee model using UKCP09 data. The results of the modelling will determine what the effect will be on the deployable output of the Dee impounding reservoirs and whether this will affect abstraction licence quantities. We understand that the EA is working on this project with a view to publication of results in 2011.

In addition to assessing the impacts of climate change on the deployable output of the River Dee system, we will also undertake an assessment using the UKCP09 data to investigate the impact on the deployable output of the company-owned water resources.

Adaptation approach to medium and low risks - short and long term impacts of climate change

While only identified as a minor environmental impact, intermittent discharge is found to have both positive and negative implications. Overall climate change is predicted to increase the frequency of spills and as such have an adverse impact on the water quality in receiving watercourses. However, while drier summer periods will increase the environmental impact of these spills, wetter winters may have the benefit of reducing the impact. This will require medium-to-long term adaptive actions.

There is an environmental and regulatory threat from pollution incidents as a result of drier summers and more variable rainfall patterns during spring and autumn. Reduced rainfall brought about by climate change may cause reduced watercourse dilution, the result of which may be tighter discharge consents and a risk to the level of service. It is currently deemed a low risk for Dee Valley Water.

For water supply and distribution, the greatest threat from climate change is to security of supply. Drier summers and more variable rainfall patterns in other seasons increase the likelihood of drought and disruptions to supply. Rising sea levels and saline intrusion into the lower reaches of the River Dee will also reduce the available resource. In addition to physical risks, there are associated regulatory risks with possible restrictions in supplies. This is the most substantial risk within this category and requires adaptive actions in the medium-term. Conversely, there is a minor opportunity in the form of increased winter rainfall bringing the potential for an increase in storage. Medium threats in this category include adverse impact on water quality as warmer temperatures increase the threat of algal blooms. Increasing salinity of water resources due to sea level rise and saline penetration will also increase treatment requirements.

In addition to direct physical impacts, climate change will have indirect impacts. An increase in population due to an influx of climate migrants may increase the demand for water. Impacts on land use planning may also impact upon the Company. The responses of other actors to climate change may also have an impact on water companies; for example local authority incentives to reduce the extent of impermeable surfaces in urban areas, in response to an increase in flood risk, may have benefits for water companies.

6 BARRIERS TO ADAPTATION AND INTERDEPENDENCIES

The main barriers to implementing the adaptation programme can be grouped under three main headings:

- costs and affordability
- resources and knowledge
- regulation.

The cost and affordability of adapting to climate change may present barriers to implementation, for example customers may not be willing to pay extra for enhanced protection of the water infrastructure to adapt to the impacts of climate change. In order to mitigate this it will be necessary to educate customers on the risks posed by climate change and the necessity for the enhancement, and to subject each measure to strict cost benefit analysis including the cost of carbon, with the most cost beneficial measure being prioritised.

The availability of adequate staff resources with suitable knowledge and expertise to deliver the climate change adaptation measures could be a barrier to implementation. The latest UKCIP forecasts pose new challenges in interpreting the scenarios and applying the probabilistic output to our historical data, and we will continue to keep up-to-date on the latest developments in collaboration with the industry.

The water industry operates in a regulated environment and relies on guidance from the Regulators to deliver certain programmes. We will continue to work with the Regulators to ensure that appropriate legislation and guidance is provided in a timely manner.

7. MONITORING AND EVALUATION

In order to ensure the management of climate change is incorporated alongside other risks that have to be managed, the corporate risk register will be used to manage the risks identified in Table 1.

The climate change risk assessments will be updated on an annual basis as part of the supply/demand balance assessment or as and when new or better information becomes available.